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enter zoology as a profession, with the well grounded hope of attaining such a position as his talents deserve.

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*THE CHEMICAL EDUCATION OF THE
ENGINEER¹*

THE academic education of the civil engineer is a thing of yesterday; or rather, it is a thing of to-day. Yesterday it was not. I use the word, "civil" in its original sense. Balbus was, without doubt, a military engineer. The great roads of antiquity were built by soldiers. In the Motherland, yours and mine, there were no roads till the Roman legions made them. On this continent, the canoe and the blazed trail were sufficient till Braddock's three hundred axemen hewed their way through the forest from the sea to Fort Duquesne, and our Governor Simcoe connected Lake Ontario with the lake that bears his name by the military road which, in imitation of the old Roman Watling Street, he called, as we call it still—Yonge Street.

But steam changed all this. With steam came railways; and with railways came the civil and the mechanical engineer, and to them has been added, in our own day, the electrical engineer. At first, the civil and the mechanical engineer learned their trade, like everybody else in those days, by apprenticeship. They learned to play the fiddle by playing the fiddle, without any lectures on the physical and the physiological bases of harmony or any exercises "zur Fingerfertigkeit." And grand musicians they were, those old masters who wrote their opera on staves of iron ruled across two continents; whose treble was the shriek of the locomotive, and whose bass was the roar of the blast furnace, whose

choruses were sung by the toilers of the nations, and whose libretto was the record of the world's progress.

It is a truism that genius often gains its end by bursting barriers and breaking rules. But for all that, we have come to think that education will not hinder the genius, and will surely help the engineer.

It is noteworthy that France, where one word stands for both genius and engineering, led the way in this matter. Engineering education dates from the foundation of the *École des Ponts et Chaussées*. Germany followed; then America, like one born out of due time, but now become the greatest of the Apostles. Nay, at last, even my countrymen, clothed as they are with a contempt for theory which throws off the undulations of the intellectual ether more completely than polished nickel, backed by a conservatism more impermeable than infusorial earth, even Englishmen are giving signs of viscosity; and British public opinion is flowing forward with a motion like that of a glacier, slow, indeed, but sure and irresistible.

We agree then that the engineer shall be educated. But shall chemistry form one of the subjects of his education? Assuredly yes. For what is an engineer? He is a man who devises and supervises the construction and use of engines—contrivances—that is, for yoking the forces of nature to the service of man; and what are chemistry and physics but the ordered and methodical study of these forces and of their action on the materials of which machines are constructed and upon which they work.

I am speaking to-day as a chemist to chemists, and it is safe to say that we are all pretty well agreed as to the kind of teaching that is best for the professional chemist, whether his career is to be technical or academic.

¹ Read at the Chicago meeting of the American Chemical Society.

So too, there are certain sufficiently obvious considerations which would guide us in shaping a chemical course for a mining engineer. Chemistry is chemistry even if you call it metallurgy and assaying; and those of us who have helped to frame a curriculum in chemical engineering know that the great problem is to keep the engineering twin from smothering his chemical brother.

About all this a great deal has been written and a great deal has been said, and we are, I think, most of us, so far, in substantial agreement.

But what about the chemical education of the civil and mechanical engineer? We may at once admit that chemical problems form but a small proportion of those which confront him. It is true that the combustion of fuel, the incrustation of boilers, and the rusting of metals, the preservation of timber, the setting of cement, the action of explosives, all involve questions of chemistry, and their consideration forms part of the daily work of the engineer. But in many such cases he can accept the results of previous investigations without troubling himself about the way they were obtained, and in others he can call in the chemist to his aid. The engineer is not a chemist, and for him chemistry must be reckoned as one of his "culture subjects." It is exactly here that the difficulty of the teacher begins. He is called upon to teach chemistry to boys who are not going to be chemists, who have no wish to become chemists and who ought not to be encouraged to think that they are being made chemists.

On the one hand, he must make his subject sufficiently interesting to attract to it a due share of that energy upon which there are so many other and, in the student's judgment, more pressing calls; and, on the other hand, he must not lead the

student to suppose that, after attending a few lectures and performing a few laboratory experiments, he will be able to pose as a chemical expert.

This is a real difficulty; and it is all the greater because chemistry is looked upon by the public as a utilitarian subject—a study which is supposed to have, as of course it has, a practical bearing upon daily life.

One of my teachers used to illustrate to his class the value of the study of mineralogy by saying to them: "Suppose a farmer brought you a bit of hard yellow mineral and said to you: 'Sir, what is this? You have attended a course of lectures on mineralogy, can you tell me if it is any good? It occurs in great abundance on my farm. Is it gold or what is it?'" And he went on to show how, with the aid of a watch glass, the student could dissipate the golden dreams of the credulous husbandman.

One of my colleagues, who is a graduate of Oxford, somewhat grudgingly admitted that it was desirable, in a new country such as Canada, that a young man should learn chemistry, because he might through its aid discover a silver mine.

The notion that chemistry is a study which has a high value as a mental training, as a means of broadening and deepening the mental outlook—in a word, as a means of culture on a par with mathematics and languages and history—is still very far from the point of view of the man in the street.

Now, the undergraduate is the son of the man in the street; and he brings to college his father's point of view, his father's prejudices, and his father's limitations—together with a cocksurety that is all his own.

Our first task then is to give the young engineer the chemist's point of view. Our

point of view is ever changing, and our view of truth changes with it and is always incomplete. It is the tangent to the curve that represents the evolution of our knowledge of the truth, and it coincides with that curve only at that infinitesimal interval of time that we call now. As we look into the future, it diverges more and more widely from the truth, and we can only keep in the true path by continually shifting our view-point and continually changing our views. This is the first thing we should teach our students. But our present view of the truth, though certainly incomplete, is not necessarily false. If our data are reliable, if our measurements are accurate, if our calculations are correct, it does really represent the facts as we now know them. It is real knowledge. It will become out of date with the lapse of time, but it will not be contradicted; it will not be exploded. This is the next thing to be taught. The recognition of these two cardinal principles constitutes the scientific habit of mind. This is essentially the difference between the mental attitude of the man of science and that of the man in the street. Our first duty is to impress this way of looking at things on the plastic minds of our pupils, not by precept only, but by example, by illustration, by reiteration till it becomes a part of their nature.

But it is not enough to give a boy the chemist's point of view. We must also try, as far as time and opportunity allow, to make him see the things the chemist sees. We must get him to look beneath the surface of the forms of matter that surround him and discern, at least in some dim way, the throbbings of the living forces within them and around them.

And here let us beware of serving up knowledge in individual platters. Do not let the student get into his head that there is one chemistry of the metals and another

of the non-metals, or that organic chemistry and inorganic chemistry have any real existence except as guide cards in a catalogue.

The student's time is so short and so crowded with other studies that only a few types can be chosen. But let those types be selected so as to cover, as far as may be, the whole field; let them be as typical as possible, and make the student understand that they are types. Thanks to the great Russian Pilot, this is an easy task now in comparison with what it used to be in the days when some of us launched our bark on the yet uncharted sea.

Above all things, let us see to it that the student never for one moment flatters himself with the notion that what we require him to know is all there is of chemistry that is worth knowing! Let us make it abundantly clear to him that we are only teaching him to read the language of chemistry and that the selections we set before him are only exercises in translation—not a *corpus poetarum*.

When I speak of teaching the student to read the language of chemistry, I am using no empty metaphor. This is the kernel of the whole matter. What we have to do is just this—to teach him to *read* chemistry; to interpret chemical phrases; to give him clear notions as to the meaning of the conventions by which the chemist expresses his ideas.

This, as I have said before, is mental training of a high order. But it is more than that. The utilitarian side of the question must not be overlooked any more than the cultural aspect. The time will come, sooner or later, when the engineer will want to find out what is known about the chemistry of some subject in which he is interested. Very likely his need will be urgent; it is certain his time will be scant. If he has had the education I speak of, he

will know where to look for information; and he can use it when he finds it. If he meets a phrase he can not construe, he will know how to use his dictionary. A statement couched in chemical language, or symbols, will not make him shut the book like a nineteenth-century chemist confronted with a sign of integration.

Nothing will arouse and retain the student's interest so effectually as frequent references to those points of contact between theory and practise, where the abstractions we are trying to teach him become concrete in the problems he will have to face.

And here let me say what I have hinted before, that it is a mistake, I am sure, to keep organic chemistry a sealed book to the engineer. If we consider the various applications of chemistry to daily life and to industry, it is surprising to note how many of them are concerned with the chemistry of the carbon compounds. Fuel, explosives, sanitation, the decay and preservation of timber, pigments, oils, paper, textile industry, fermentation, the preparation and preservation of food, all have to do with organic chemistry. Let any one read a list of patents, or the classification of abstracts in the *Journal of the Society of Chemical Industry*, and this will be made abundantly clear.

It may be objected that in the time at his disposal the student can only acquire a smattering of this great subject, and that such a smattering is worse than useless. I readily grant the first contention, but I emphatically deny the second. If by the abusive term "smattering" we mean a little knowledge, then that smattering is dangerous only when it carries with it unconsciousness of its own littleness, and I hope I have made myself sufficiently clear as to the importance of keeping always before the student his own limitations.

The cure for superficiality, that bugbear of the pedant, is not to blindfold the eyes, but to train the eyesight, and the student whose mental vision is thus sharpened will not only be able to see clearly the things that lie before him and about him on the threshold of our science, but he it is who will most readily discern the vastness and the richness of the territory at whose frontier he stands; and he who will most humbly and most surely walk in any of its paths along which his business or his pleasure calls him.

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SCIENTIFIC BOOKS

The Integrative Action of the Nervous System. By CHARLES S. SHERRINGTON. New York, Charles Scribner's Sons. 1906. Pp. xvii + 411. \$3.50.

This volume contains the Silliman Memorial Lectures delivered at Yale University in 1904. In it the author focuses the work which he has carried on with such assiduity on the functions of the central nervous system considered as an organ for coordination. This side of nervous physiology has perhaps received less attention of late than the study of the activities of the individual nerve fiber or cell; though, to be sure, the author is able to refer to a long list of fellow workers, brought together into a valuable bibliography, among whom the most prominent are perhaps Exner and Goltz. It may, however, be safely said that the author's own contributions, in range and precision, now entitle him to rank at the head of students of this phase of the subject. The function of nervous tissue is, in a word, to conduct, and so to integrate—to enable the organism, in reacting on its environment, to act as a harmonious whole. To understand this function, one must, of course, penetrate the mystery of nerve conduction; but besides, and to some extent independent of that, one must know what are the paths of conduction and how they are interrelated. The present work is not concerned specially with topog-